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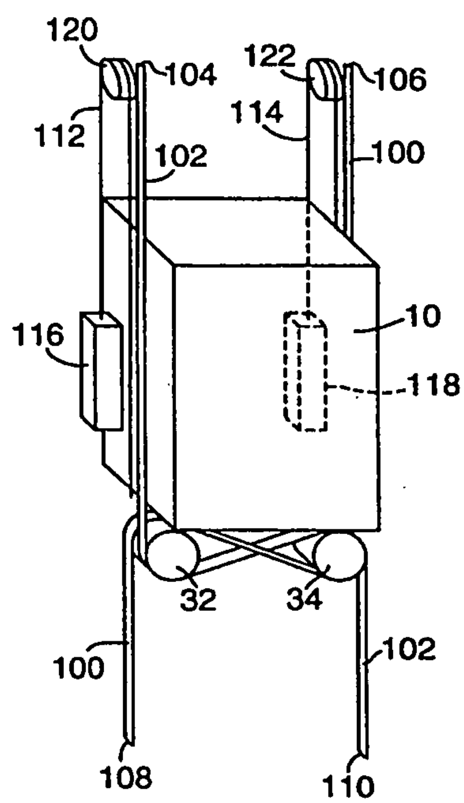
(54) Title: DUAL SHEAVE ROPE CLIMBER USING FLAT FLEXIBLE ROPES

(57) Abstract

A self-climbing elevator (10) includes drive or traction sheaves (32, 34) secured to the car and adapted to engage stationary traction ropes (100, 102).



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Dual Sheave Rope Climber Using flat Flexible Ropes

Technical Field

The present invention relates to a rope climbing elevator.

Background of the Invention

Typical roped or hydraulic elevators in current use consist of a cab which is moved vertically within a hoistway shaft by means of an external mechanism, such as a traction machine for roped elevators and an hydraulic piston and pump for hydraulic elevators. The location of the machinery associated with such external hoisting machines can be problematic in certain types and arrangements and buildings.

Designers have attempted to address the these problems by proposing self-propelled elevators in which the lifting mechanism is integral with the elevator car, thus avoiding the need for a machine room or other designated space to house the elevator lifting machinery. Various prior art designs have utilized rack and pinion arrangements in which a geared pinion on the elevator car engages a linear rack disposed vertically in the hoistway, linear induction motors wherein the primary and secondary armatures are disposed on the elevator car and hoistway, respectively, and other means which will readily occur to those skilled in the art. Each has various drawbacks in terms of speed, power consumption, ride quality, etc., and none have achieved wide-spread acceptance or use.

Disclosure of the Invention

It is an object of the present invention to provide a self-propelled, rope climbing elevator.

According to the present invention, an elevator car is provided with at least one pair of counter-rotating traction sheaves which are driven by one or more prime movers

which are also secured to the car. Each sheave receives a corresponding stationary rope, secured at the upper end of the elevator hoistway, and hanging vertically downward. Each rope is wrapped partially about the lower portion of its corresponding sheave, and partially about the upper portion of the other paired sheave, hanging vertically downward therefrom. The lower, or free, end of each rope is then tensioned by a suspended weight, spring or the like.

In operation, the driven traction sheaves rotate, causing the car to move vertically within the hoistway by translating the cab relative to the stationary ropes.

In a second embodiment of the present invention, a second elevator car is operable within at least a portion of the hoistway traversed by the first car. The respective ropes and sheave pairs are located so as to avoid interference between the cars during operation, thus allowing the two cars to run simultaneously in the same hoistway.

In a third embodiment of the present invention, the hoistway includes a plurality of rope clamps adapted to engage the stationary ropes and support a portion of their weight, particularly in high-rise applications in which the length and weight of the rope is very great. The clamps release upon approach of the car and are re-engaged after the car passes. By providing intermediate support of the rope, the clamps permit use of very long ropes which would otherwise not be suitable in this application.

In a fourth embodiment of the present invention high-friction, flat, flexible traction ropes are used for efficient and increased traction between rope and sheave, thereby reducing machine mass and system cost. The increased traction is attributable to the increase in surface contact area attained with flat ropes, as

opposed to conventional, round ropes. By utilizing flat ropes instead of round ropes the number and diameter of drive or traction sheaves may be decreased. This reduces machine cost in general and in particular instances where, for example, only one sheave needs to be driven rather than two. Because the diameter of the drive sheave can be reduced, the torque required to drive the sheave will, as a result, be decreased. Thus, smaller and more efficient drive machine components can be used. By minimizing the number and size of drive sheaves and drive machine components, cost-efficient and smaller, lighter weight machines can be implemented. This is particularly advantageous in a system, such as the present invention system, where the machine and the drive sheaves are supported by and move with the elevator car.

In a fifth embodiment of the present invention, a novel sheave and rope or belt arrangement is illustrated in which a traction rope or belt engages a drive sheave in an approximate 360 degree wrapping fashion for optimum traction. Such an arrangement provides maximum traction with minimum components, material mass, space and associated costs.

In a sixth embodiment of the present invention, a novel sheave and rope or belt arrangement is illustrated in which optimum traction with minimal components, material mass, space and cost is achieved by providing a pair of diverter sheaves in positions so as to optimize the area of wrap-around contact between a rope and drive sheave.

Brief Description of the Drawings

Fig. 1 shows an embodiment of the present invention without the surrounding hoistway.

Fig. 2 shows a more detailed plan view of the sheave arrangement as shown in Fig. 1.

Fig. 3 shows a side elevation of the sheave arrangement according to the present invention.

Fig. 4 shows a side elevation of the second embodiment of the present invention.

Figs. 5 and 6 show respective plan views of the sheave arrangement of the first and second elevator cars of Fig. 4.

Fig. 7 shows a third embodiment of the present invention having a plurality of rope clamping means shown in Figs. 8, 9a, 9b and 10.

Fig. 11 is a schematic, perspective view of a fourth embodiment of the present invention system using flat ropes with traction sheaves.

Fig. 12 is a schematic, partial perspective view of a component of a fifth embodiment of the present invention.

Fig. 13 is a schematic, partial perspective view of a component of a sixth embodiment of the present invention.

Fig 14 is a sectional, side view of a traction sheave and a plurality of flat ropes, each having a plurality of cords.

Fig. 15 is a sectional view of one of the flat ropes.

Best Mode for Carrying Out the Invention

Referring now to the drawing Figures, and in particular to Fig. 1, a first embodiment according to the present invention will be described in detail. Fig. 1 shows an elevator car 10 disposed within a hoistway shaft (not shown). A plurality of vertical ropes 12-26 hang in two groups of four vertically downward from upper securing points 28,30. The ropes engage counter rotating paired drive sheaves 32,34 disposed, in this embodiment beneath the elevator car 10 in a manner as will be further described. Each group of ropes 12-18 and 20-26 terminate at their lower vertical ends at respective weights 36,38 or other

tensioning means, including springs, hydraulic actuators, electromagnetic actuators or any other means well known in the art for imparting a tensile force a rope.

Referring now particular to Figs. 2 and 3, the operation of a rope climbing elevator according to the present invention may be described. Drive sheaves 32,34 are driven in opposite directions by prime movers 40,42, respectively. As shown in Fig. 3, rope 20, hanging vertically downward within the hoistway shaft (not shown) and outside of the travel volume of the elevator car 10, passes underneath drive sheave 34, turning laterally and vertically upward to pass over drive sheave 32, turning again vertically downward and terminating at tensioning weight 38 in the lower portion of the hoistway shaft. In describing this path, rope 20 engages a substantial arc 44 on the lower portion of sheave 34 and a similar size arc 46 on the upper portion of drive sheave 32. The substantial engagement arc with the drive sheaves 32,34, coupled with the tension provided in rope 20 by means of that portion hanging vertically downward from drive sheave 32 as well as any tension force provided by the tension means 38, allow the sheave and rope system shown in Figs. 1 - 3 to achieve sufficient traction to cause the counter rotation of sheaves 32,34 to drive the elevator vertically upward or downward as desired. As will be appreciated by those skilled in the art, ropes 12-18 and 22-26 shown in Figs. 1 and 2 each engage corresponding upper and lower portions of drive sheaves 32,34 as described for rope 20 above.

Prime movers 40,42 are shown schematically and are representative of any of a number of well known means for imparting controllable counter rotation to sheaves 32,34 with sufficient power to lift the elevator car 10 and its contents in the manner described. As such, the prime mover or prime movers may be powered by electricity, and coupled to the sheaves either mechanically by means of gears, chains, belts, or the like, hydraulically or directly, depending upon the required power, or other application specific parameters. Although it is believed

preferable, due to load balancing, torque balancing, smoothness, and other considerations, that both sheaves 32,34 be driven in a counter-rotating direction, the elevator arrangement according to the present invention is operable using only one driven sheave with the other sheave serving as an idler.

Power may be supplied to the moving car 10 and driving means 40,42 by means of any of a number of arrangements well known and used currently in the art, including vertically oriented electrical bus bars disposed on the hoistway wall and moving contacts disposed on the elevator car, a traveling cable running between the car and a power connection point on the elevator wall, etc.

The embodiment as described above and shown in Figs. 1 - 3 permits the elevator car 10 to operate vertically without the need for a separate machine room in an extended overhead space (not shown) or in a lower pit area (not shown). Further, the arrangement as shown and described does not require a moving counterweight or other similar arrangement to tension the ropes passing over the drive sheaves thereby avoiding the need to provide additional space within the hoistway to accommodate the vertically moving counterweight. As such, elevator systems according to the present invention may be particularly well suited for older or modern buildings for which there is a need to provide elevator service while accommodating limitations on the amount of space available for use. Alternatively, the use of a separately roped counterweight arrangement, (not shown) may be used to reduce the prime mover power requirement.

As will be further appreciated by those skilled in the art, the arrangement according to the present invention will permit the elevator prime mover 40,42, or machine, the motor drive (not shown) and controller (not shown) to be packaged, thus reducing shipping and installation time and cost.

Figs. 4 - 6 show a second embodiment of the elevator system according to the present invention. As in the first embodiment, Fig. 4 shows a plurality of stationary ropes disposed in two groups 50,52 secured at their respective upper

ends 54,56 and hanging vertically downward, terminating at the lower ends with respective tensioning means 58,60. In addition to the first car 10, however, this second embodiment includes a second car 62 which is operable within at least a portion of the vertical travel elevator of the first car 10 as described below.

As may be viewed clearly in Figs. 5 and 6, cars 62 and 10 each include counter-rotating drive sheaves 64,66 and 70, respectively. The counter-rotating sheaves 64,66 of the upper car 62 each first engage respective groups of ropes 50,52 as described for the first embodiment.

With regard to car 10, drive sheave pairs 68,70 likewise engage opposite rope groups 51,53 disposed laterally outside of the travel volume of the elevator cars 10,62 and adjacent ropes 50,52 engaged by car 62.

The operation of the second embodiment according to the present invention may now be understood. Elevator cars 10,62 may each simultaneously occupy a position within a shared travel volume 72 each servicing the same floor via the same hoistway shaft and doors. As each car contains an independent prime mover, and as the shared vertical travel zone 72 is unoccupied by any central ropes or other impediments, the elevators are constrained, in this embodiment, only by the restriction that they are unable to pass each other in the vertical direction. Vertical tensioning means 58,60 shown in Fig. 4 comprise a plurality of individual weights, secured to each rope or group of ropes, or individual spring or hydraulic tensioning members as discussed herein.

The flexibility of the second embodiment according to the present invention, provides increased flexibility, load capacity and other features in a single vertical hoistway. For extremely high-rise applications, transfer between banks of elevators in a sky lobby or other transfer arrangement may be accomplished by exiting a car traversing, for example, a lower range of floors and reentering, via the same lobby door, an elevator car servicing an upper range of floors. Other possibilities include, for example, dispatching an express elevator

from an entrance level floor during a peak period which operates non-stop to an upper floor, while providing a local elevator car, at the same lobby entrance to follow servicing intermediate lower floors. These and other arrangements and advantages will become obvious to those skilled in the art having appreciated the flexibility and functionality provided by elevator system according to the present invention.

Fig. 7 - 10 illustrate a third embodiment of an elevator system according to the present invention which is particularly adapted for ultra high-rise buildings. Extremely high-rise buildings serviced by roped elevators face a limitation due to the physical characteristics of the steel elevator ropes commonly used. Conventional steel ropes, regardless of their design, become unsuitable in applications wherein the elevator range of travel is over 300 meters. At such lengths, the freely hanging steel rope becomes unable to bear its own weight and that of the car. The third embodiment of the present invention takes advantage of the fact that the elevator system according to the invention utilizes only stationary ropes to address this problem.

Fig. 7 shows an elevator car 10, primarily as described and shown in Fig. 1, having drive sheaves 32,34 and prime movers 40,42 engaging stationary ropes 12,20. For the purposes of illustration, only ropes 12 and 20 will be discussed, however, it will be appreciated that multiple ropes as shown in the preceding embodiments may be utilized as necessary. Ropes 12,20 are secured at their upper ends at stationary points 28,30 and tensioned as necessary at their lower ends by weights or other tensioning means 36,38. The third embodiment provides means for supporting the vertical stationary ropes 12,20 particularly wherein the unsupported rope may be in danger of failing under its own weight. This is accomplished in the embodiment of Fig. 7 by means of a plurality of clamping means shown secured vertically to the building structure such as the hoistway wall 74. The clamps are retractable between an extended engaged condition, as

shown in Fig. 9b wherein a releasable clamp 76 engages the rope 12 and a retracted, released position as shown in Fig. 9a wherein the clamp 76 is released and retracted toward the hoistway wall 74. Retraction may be accomplished by a number of well known means, including an hydraulic or electric actuator 78 as shown in the Figures. The support means 72 are shown disposed at one or more locations vertically along the hoistway 74 spaced vertically as required to provide intermediate support of the ropes 12,20 between the upper attachment points 28,30 and the lower tensioned ends.

As will be apprcciated by viewing Fig. 7, as elevator car 10 traverses vertically through the hoistway 74, clamps 72 are released upon approach of the car thereby freeing ropes 12,20 for engagement by the drive sheaves 32,34, and reengaged upon passing of the car 10 to provide intermediate vertical support. Fig. 8 shows a first series of clamps 72' which are disengaged due to the proximity of the car 10, and a second group of clamps 72'' which will be reengaged following the passage of the car vertically upward. Fig. 10 shows a schematic of a support means as may be used in an elevator system according to this embodiment of the invention. As noted above, the device includes a releasable rope engaging clamp 76, a retracting means 78 secured to the hoistway wall 74, and a variable supporting actuator 80 for providing the necessary vertical supporting an equalizing force to the rope 12 so as to provide the necessary intermediate support to avoid excessive tensile stress. The equalizing force is preferable equal to the weight of the rope segment between adjacent rope clamps 76. The embodiment in Fig. 10 also shows a spring or other tensioning means 82 provided here as a biasing means for optimizing the delivery of vertical supporting force to the rope 12 via the clamp 76. It may be appreciated that, under certain conditions, it may be desirable to monitor the actual tensile stress in the rope 12 and operate the support force actuators 80 accordingly.

It will further be appreciated upon a review of the second and third embodiments, that the elevator system according to the third embodiment is likewise easily adapted to the operation of one or more additional elevator cars within the same travel range.

Likewise, the location of the driving sheaves and prime movers on the upper portion of the elevator car, as well as the use of double deck cars, or the like, should also be appreciated as being within the scope of the invention, which has been disclosed herein an exemplary, and not exhaustive, manner.

A fourth embodiment of the present invention elevator system, as shown in Fig. 11, illustrates the use of a novel rope arrangement which includes flat traction ropes or belts used with drive or traction sheaves. The terms "flat ropes" or "flat belts" as used herein refer to ropes or belts having an aspect ratio greater than one, where the aspect ratio is defined as the ratio of the rope or belt width to thickness. An elevator car (10), substantially as described with respect to Fig.1, has drive traction sheaves (32, 34) operatively coupled to respective prime movers (not shown). The traction sheaves (32, 34) engage stationary, flat ropes (100, 102). The flat ropes (100, 102) are secured at their upper ends (104, 106) at stationary points and tensioned as necessary at their lower ends (108, 110) by weights (not shown) or other conventional tensioning means (not shown). Suspension ropes (112, 114) are utilized for suspending the elevator car (10) and counterweights (116, 118). The suspension ropes (112, 114) may be of any suitable type such as conventional, round steel ropes. As shown in Fig. 11, the suspension ropes (112, 114) are fixed at one end to the elevator car (10) and at the other end to a respective counterweight (116, 118). Respective idler pulleys (120, 122) for the suspension ropes (112, 114) are attached to a stationary object such as a guide rail (not shown) or an overhead beam (not shown). Torque power can be supplied through one or both sheaves (32, 34).

Implementation of the system of the fourth embodiment provides for a lower system mass and installed cost for self-propelled elevators, lower torque requirements and associated costs, and other benefits including reduced installation time, maximum installation in the factory, elimination of the machine room, and minimal building interface.

Referring to Fig. 12, there is disclosed a novel drive sheave and belt or rope arrangement (200) that may be implemented with the elevator system described in the foregoing embodiments. The drive sheave (210) is configured in such a way so that the drive rope (212) or belt can be wound around the sheave (210) to contact it over an area of approximately 360 degrees around. This is accomplished by off-setting the positions of the rope ends (214, 216) along a direction generally parallel to the rotational axis of the drive sheave (210). The drive sheave (210) may have rope guiding means such as grooves (218) or the like in order to guide the rope or belt (212) as it makes contact. The grooves (218) may be arranged in a spiral manner around the circumference of the sheave (210). The rope (212) may be a flat rope or belt, or a round rope.

Referring to Fig. 13, there is disclosed another embodiment of a novel drive sheave and belt or rope arrangement (300) that may be implemented with the elevator systems described in the foregoing embodiments. A drive sheave (310) receives a rope or belt (302). Two or more diverter sheaves (304, 306) maintain the rope or belt (302) in a position such that the rope or belt (302) is held in contact around a desired area of the circumference of the drive sheave (310), such as an area exceeding 180 degrees around the sheave (310). The diverter sheaves (304, 306) may be selectively positioned to vary the degree of wrap around the sheave (310).

The components illustrated in and described with respect to Fig. 12-13 may be assembled in a variety of ways including, for example, a system in which

a diverter sheave is positioned at both ends of a drive rotor, thus maximizing traction with minimal motor mass.

A principal feature of the present invention is the flatness of the ropes used in the above described elevator system. The increase in aspect ratio results in a rope that has an engagement surface, defined by the width dimension "w", that is optimized to distribute the rope pressure. Therefore, the maximum rope pressure is minimized within the rope. In addition, by increasing the aspect ratio relative to a round rope, which has an aspect ratio equal to one, the thickness "t1"of the flat rope (see Fig. 15) may be reduced while maintaining a constant cross-sectional area of the portions of the rope supporting the tension load in the rope.

As shown in Fig. 15 and 16, the flat ropes 722 include a plurality of individual load carrying cords 726 encased within a common layer of coating 728. The coating layer 728 separates the individual cords 726 and defines an engagement surface 730 for engaging the traction sheave 724. The load carrying cords 726 may be formed from a high-strength, lightweight non-metallic material, such as aramid fibers, or may be formed from a metallic material, such as thin, high-carbon steel fibers. It is desirable to maintain the thickness "d" of the cords 726 as small as possible in order to maximize the flexibility and minimize the stress in the cords 726. In addition, for cords formed from steel fibers, the fiber diameters should be less than .25 millimeters in diameter and preferably in the range of about .10 millimeters to .20 millimeters in diameter. Steel fibers having such diameter improve the flexibility of the cords and the rope. By incorporating cords having the weight, strength, durability and, in particular, the flexibility characteristics of such materials into the flat ropes, the traction sheave diameter "D" may be reduced while maintaining the maximum rope pressure within acceptable limits.

The engagement surface 730 is in contact with a corresponding surface 750 of the traction sheave 724. The coating layer 728 is formed from a polyurethane material, preferably a thermoplastic urethane, that is extruded onto and through the plurality of cords 726 in such a manner that each of the individual cords 726 is restrained against longitudinal movement relative to the other cords 726. Other materials may also be used for the coating layer if they are sufficient to meet the required functions of the coating layer: traction, wear, transmission of traction loads to the cords and resistance to environmental factors. It should be understood that although other materials may be used for the coating layer, if they do not meet or exceed the mechanical properties of a thermoplastic urethane, then the benefits resulting from the use of flat ropes may be reduced. With the thermoplastic urethane mechanical properties the traction sheave 724 diameter is reducible to 100 millimeters or less.

As a result of the configuration of the flat rope 722, the rope pressure may be distributed more uniformly throughout the rope 722. Because of the incorporation of a plurality of small cords 726 into the flat rope elastomer coating layer 728, the pressure on each cord 726 is significantly diminished over prior art ropes. Cord pressure is decreased at least as $n^{-1/2}$, with n being the number of parallel cords in the flat rope, for a given load and wire cross section. Therefore, the maximum rope pressure in the flat rope is significantly reduced as compared to a conventionally roped elevator having a similar load carrying capacity. Furthermore, the effective rope diameter 'd' (measured in the bending direction) is reduced for the equivalent load bearing capacity and smaller values for the sheave diameter 'D' may be attained without a reduction in the D/d ratio. In addition, minimizing the diameter D of the sheave permits the use of less costly, more compact, high speed motors as the drive machine.

A traction sheave 724 having a traction surface 750 configured to receive the flat rope 722 is also shown in Fig. 14. The engagement surface 750 is

complementarily shaped to provide traction and to guide the engagement between the flat ropes 722 and the sheave 724. The traction sheave 724 includes a pair of rims 744 disposed on opposite sides of the sheave 724 and one or more dividers 745 disposed between adjacent flat ropes. The traction sheave 724 also includes liners 742 received within the spaces between the rims 744 and dividers 745. The liners 742 define the engagement surface 750 such that there are lateral gaps 754 between the sides of the flat ropes 722 and the liners 742. The pair of rims 744 and dividers, in conjunction with the liners, perform the function of guiding the flat ropes 722 to prevent gross alignment problems in the event of slack rope conditions, etc. Although shown as including liners, it should be noted that a traction sheave without liners may be used.

While the preferred embodiments have been herein described, it is acknowledged that the specific features may be varied somewhat without departing from the scope of the presently claimed invention.

What is claimed is:

1. An elevator system comprising :
a self-propelled elevator car adapted to drive along a rope.

2. An elevator system according to claim 1, further comprising
a drive sheave attached to said elevator car and adapted to engage said rope so that said rope wraps around said drive sheave in a 360 degree manner.

3. An elevator system according to claim 1, further comprising
a drive sheave attached to said elevator car and adapted to engage said rope so that said rope winds around said drive sheave in a spiral fashion.

4. An elevator system according to claim 3 wherein
said rope is a round rope.

5. An elevator system according to claim 3 wherein
said rope is a flat rope.

6. An elevator system according to claim 1, further comprising
a drive sheave attached to said elevator car and adapted to engage said rope ; and
a pair of diverter means, each positioned to cooperatively position said rope relative to said drive sheave in such a way as to cause the rope to wrap around at least 180 degrees of said drive sheave.

7. An elevator system comprising :

a vertical hoistway ;

an elevator car, disposed within said hoistway, including first and second spaced apart sheaves having parallel axes or rotation ; and

a first and second flat rope, each flat rope extending vertically in the hoistway through a range of travel of said car, each flat rope secured at a vertically upward end thereof wherein said first flat rope passes laterally under said first sheave, vertically upward between said first and second sheaves, and laterally over said second sheave, wherein said second flat rope passes laterally under said second sheave, vertically between said second and first sheaves, and laterally over said first sheave ; and

means for driving one of said first and second sheave.

8. An elevator system according to claim 7, wherein

said flat ropes are disposed at the periphery of said hoistway and outside the volume traversed by said car.

9. An elevator system according to claim 7, wherein

the lower vertical end of each first and second flat rope is secured to tensioning means for tensioning said corresponding flat rope.

10. An elevator system according to claim 9, wherein

said tensioning means comprise a suspended weight.

11. An elevator system according to claim 9, wherein

said tensioning means comprise a spring.

12. An elevator system according to claim 9, wherein
said tensioning means are adapted to impart variable tensile forces on said flat ropes.

13. An elevator system according to claim 7, further comprising
a pair of suspension ropes, each secured at one end to said elevator car and each secured and the other end to a counterweight ; and
a pair of idler pulleys, each corresponding to one of said suspension ropes and suspending said elevator and one of said respective counterweights.

14. An elevator system according to claim 9, wherein
each said suspension rope is a round rope.

FIG.1

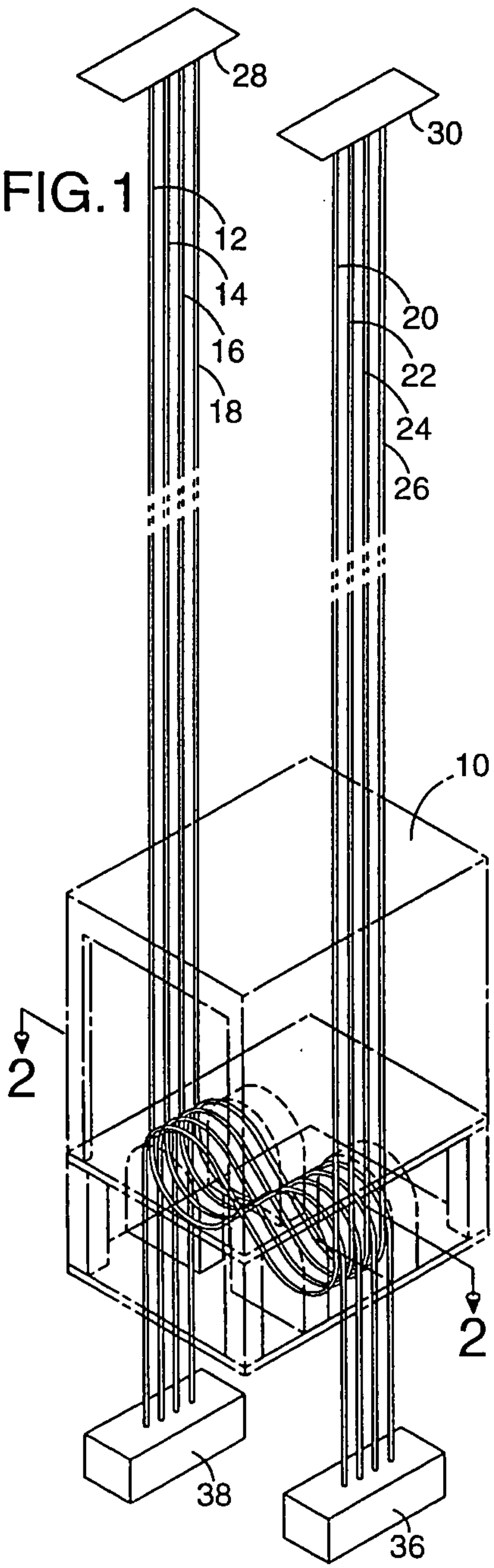


FIG.2

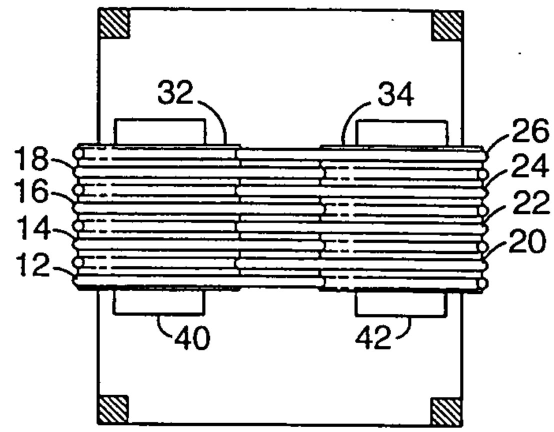
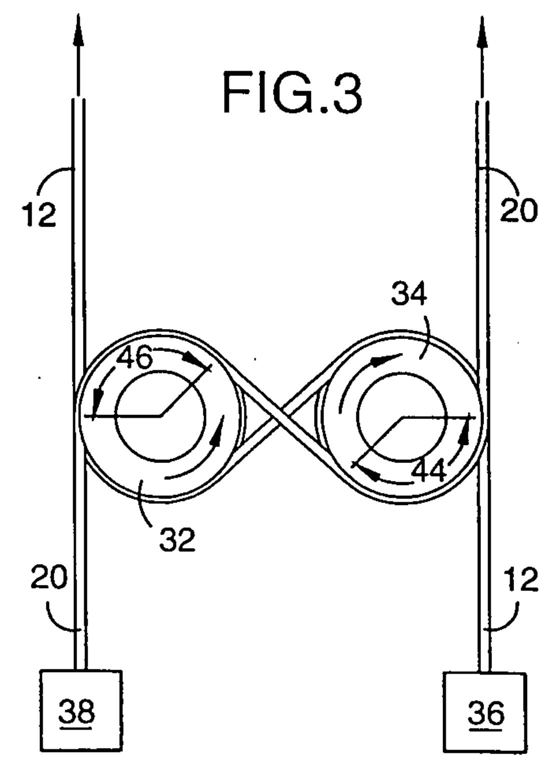


FIG.3



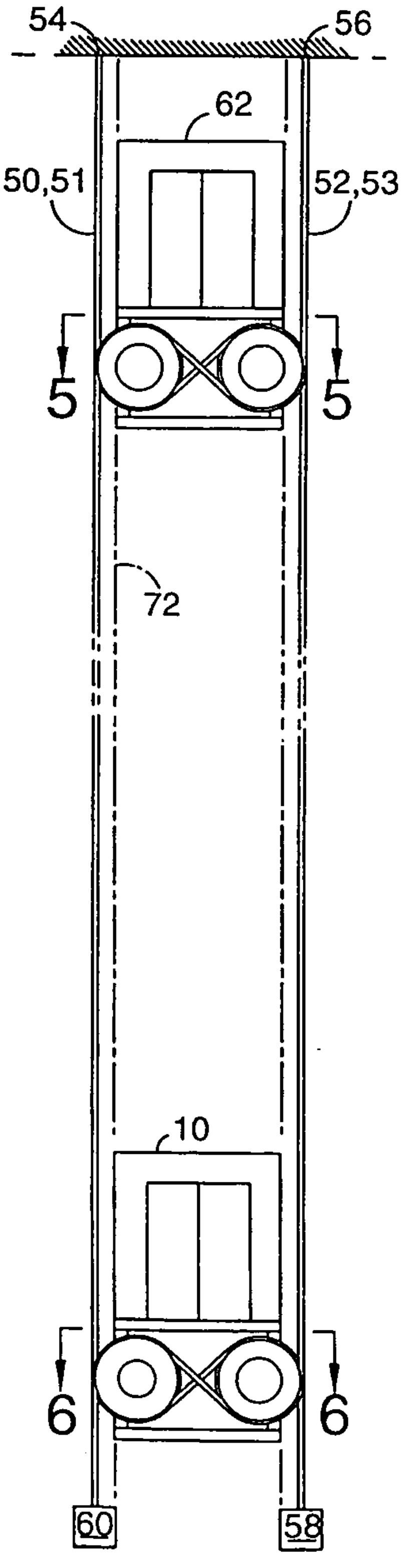


FIG.4

FIG.5

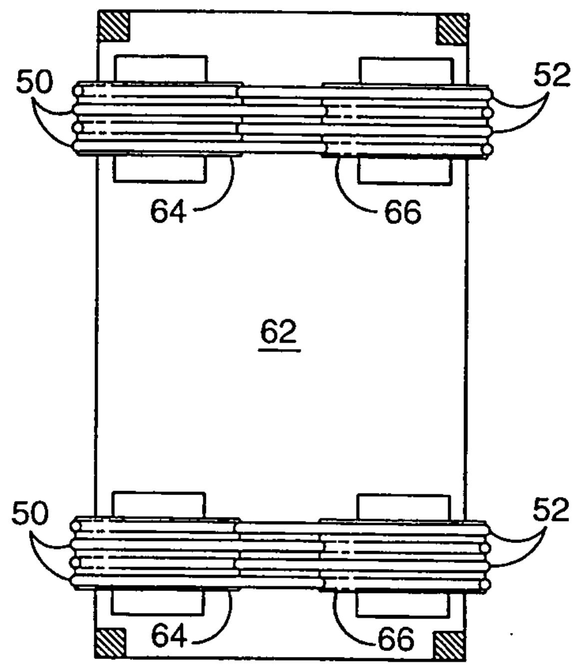
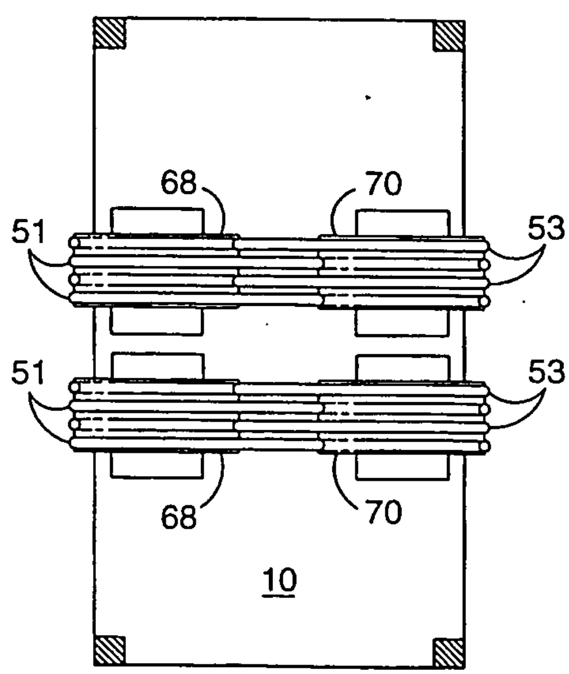


FIG.6



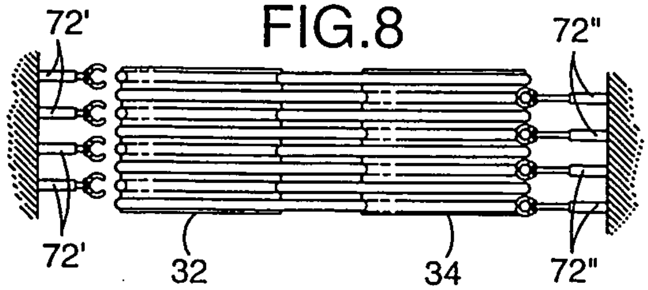


FIG.8

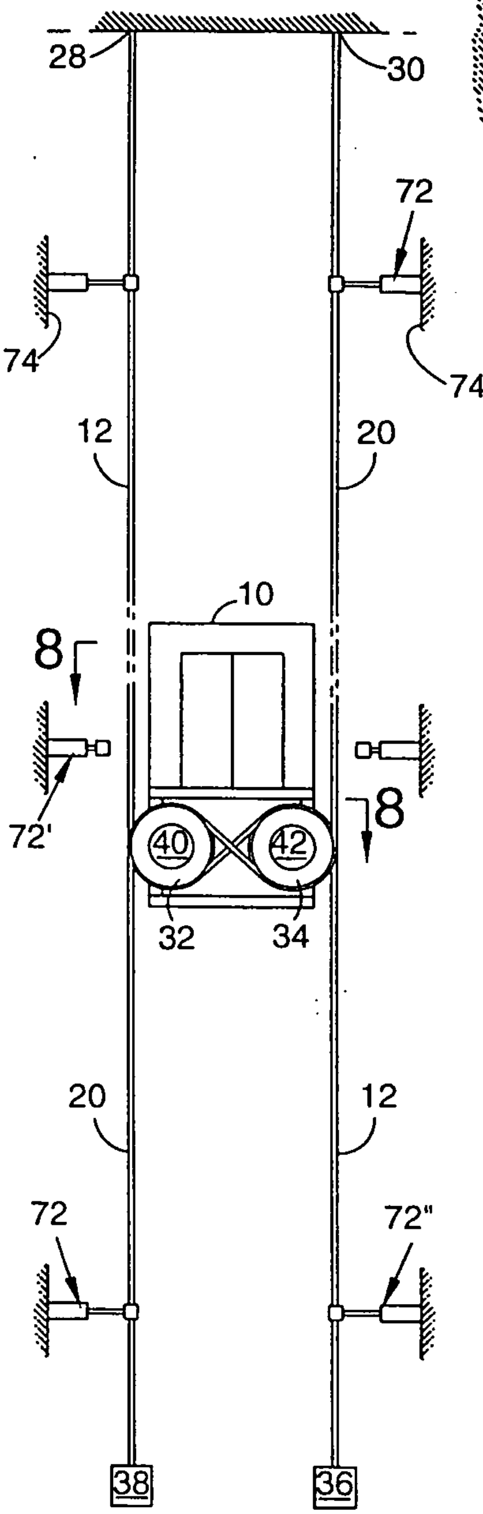
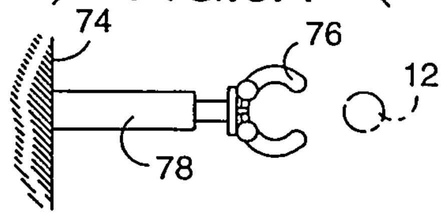


FIG.7

FIG.9A



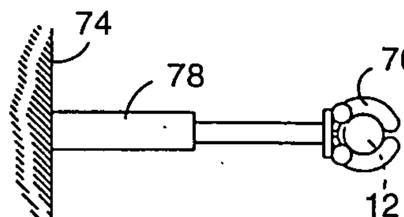


FIG.9B

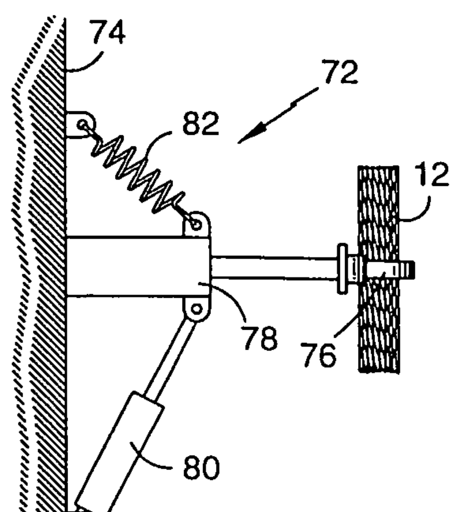


FIG.10

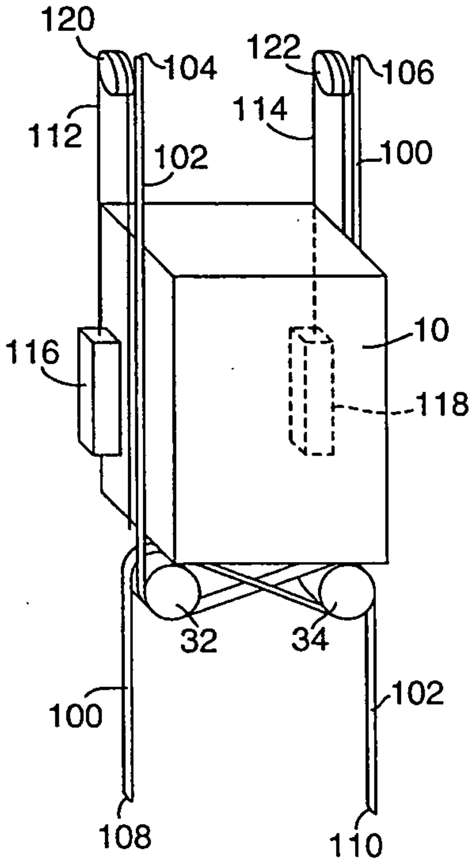


FIG. 11

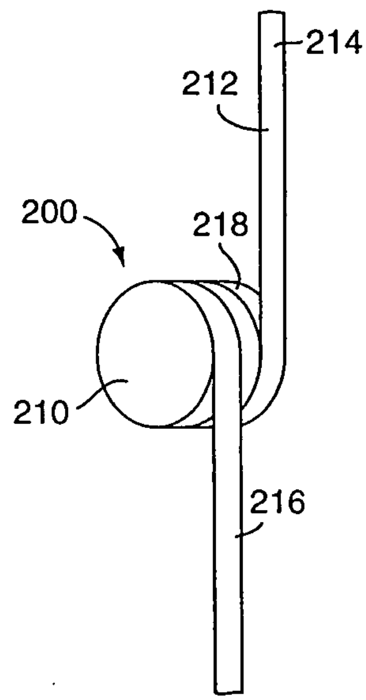


FIG. 12

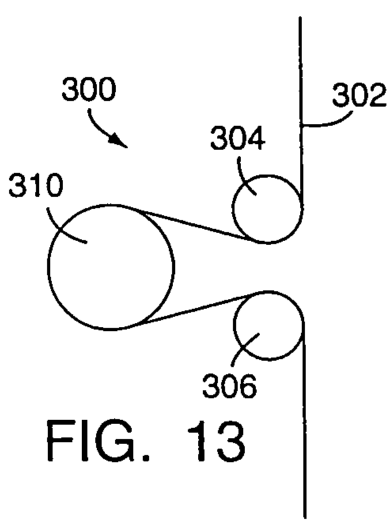
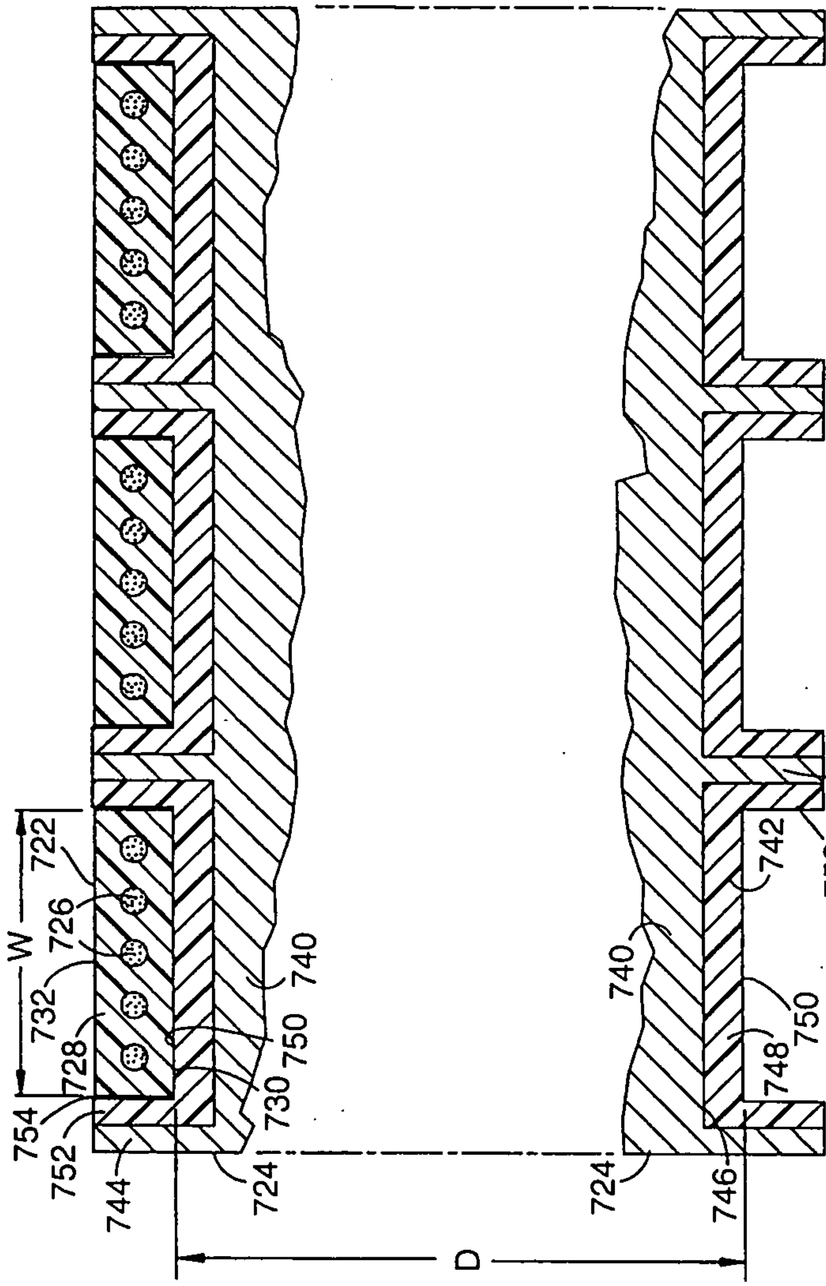


FIG. 13


722
W
726
732
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754
752
744
724
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745
D

FIG. 14

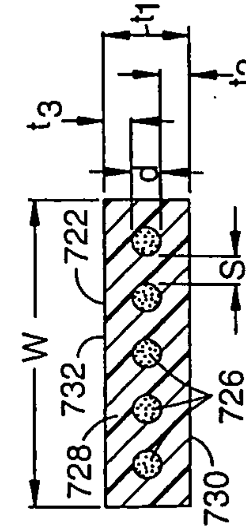
t1
t2
t3
d
722
W
732
728
730
726
S

FIG. 15